A STUDY OF THE TERTIARY FLORAS OF THE ATLANTIC AND GULF COASTAL PLAIN.[1]

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Introductory.

The observations recorded in the following pages may be said to represent a preliminary sketch of a small chapter in the study of the South Atlantic and Gulf Coastal plain undertaken by the United States Geological Survey in coöperation with the various state surveys under the direction of Dr. T. W. Vaughan.

Neither geologist nor biologist fully appreciates the magnitude, complexity or uniqueness of the coastal plain of the southeastern United States. The present coast line, a boundary first recognized by the aborigines and early explorers and so emphasized by geographers, is from the standpoint of the student of geologic history a continually shifting demarcation which does not, nor perhaps never, marked the seaward limit of the physiographic unit known as the Coastal Plain Province, for the gently sloping land surface continues seaward beneath the waves of the present Atlantic and Gulf waters varying distances up to 100 miles or more and then precipitately descends several thousand feet in a few miles, forming the majestic escarpment which is regarded as the continental boundary. In the past the coast line has advanced inland over the present emerged portion of the coastal plain and receded seaward over the present submerged margin, many times. At one time the waves of the Gulf of Mexico broke in southern Illinois, at another they were confined 100 miles south of the present sites of Mobile and New Orleans, 600 miles to the southward.

On the whole, the history of events in Tertiary times has been a progressive adding to the land area of the continent, the most im-

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portant elevation being that of the early Miocene which was followed by a subsidence, which was, however, less in extent than those which had preceded it.

No part of the coastal plain is so favorably situated for the study of the floras which preceded the present, extending backward to a time which marks the first recorded appearance of angiosperms, as that of the Gulf states. No single part of North America contains so continuous a series of Tertiary deposits carrying fossil plants. Here we find abundant floras in the lower and middle stages of the Eocene, considerable floras in the Oligocene, some in the later Miocene, and rather abundant fossil plants in the Pliocene. The Rocky Mountain region is rich in Eocene fossil plants and there are some Miocene floras, but no Oligocene or Pliocene floras are known. The Pacific coast region likewise furnishes Eocene and Miocene fossil plants but none of Oligocene age. The fossil floras of the coastal plain are found in an area where it is possible to attain to some measure of accuracy in predicating the general character and course of ocean currents and winds and other physical features of the environment. On the other hand the western floras just mentioned grew in areas where vulcanism was great at times; in areas of great orogenic activity, where changes in topography were numerous and elevations of several thousands of feet are recorded; areas in which climatic conditions not only varied from place to place, but passed through a large cycle of secular changes. All these factors greatly complicate the floral history.

The floras of the southern coastal plain are moreover checked for the most part by very abundant marine faunas in intercalated beds, or the plant-bearing beds which represent the coastal swamps and the shallow water deposition of the old embayment merge laterally with the contemporaneous limestones or marls which were forming in more open waters along the coasts to the southward, so that there is a considerable body of facts bearing on depth, character of the bottom, and marine temperatures, with which to compare land temperatures. These criteria have been admirably worked out for the Florida area by Doctors Dall and Vaughan for the post-Eocene and their results furnished a reliable datum plane for the deductions to be derived from the study of the fossil floras of these times.

So far as I know I was the first paleobotanist to explore the south Atlantic and Gulf coastal plain and that exploration has only just begun. Professors Fontaine and Ward visited the region and collected a few Cretaceous plants a score of years ago. Professor Lesquereux a generation and a half ago described a few Eocene plants collected by Professor Hilgard in Mississippi and by Professor Safford in Tennessee, and Doctors Knowlton and Hollick have identified various small collections made by others in different parts of this vast area.

With the exception of fragments of the petrified stems of conifers, palms and dicotyledons the plant-remains are in the form of impressions, mostly of foliage, but with a goodly sprinkling of fruits and seeds, and in some few cases even flowers are preserved.

While the oscillations of the Gulf area have been numerous they have been, as I have just mentioned, inconsiderable in amount, only a few hundred feet at most, and the coastal region has uniformly been one of slight relief. The various floras show a complete absence of upland types. This is in striking contrast to the European older Tertiary floras. The only large area of the globe which has been thoroughly studied, Europe, was far less stable than this region in Tertiary times and lying much farther toward the pole was subjected to the rigors of Pleistocene conditions whose influence never reached our southern states.

The object of the writer's work may be classed under three heads: (1) To determine the correlation of the various Tertiary formations particularly in the upper portion of the Mississippi embayment where marine fossils are largely absent, (2) To obtain data regarding the physical conditions under which the various floras flourished, (3) To accumulate biological data regarding the geographical distribution, specific differentiation and evolution of the Tertiary floras.

Thus one of the principal phases of the study for the geologist might be embraced under the term paleoecology. The methods include a study of the old shore lines of the different epochs, of the character of the sediments and their genesis, of the contained animals and plants, and the alternative climatic and edaphic factors which their grouping may indicate.

It is the chronologic and ecologic aspects upon which I wish to dwell in the present connection.

The paleobotanical record of the Atlantic and Gulf coastal plain furnishes a history which extends back as I have just mentioned beyond the oldest known angiosperm to a time (Lower Cretaceous) when the flora was made up almost entirely of tree-ferns, conifers and those interesting cycadophytes (*Cycadeoidea*) whose trunks are sometimes preserved with such marvelous perfection that the outlines of the embryos in the ovules can often be made out in detail. Coming a step nearer my present theme, a step of some millions of years from the Lower into the Upper Cretaceous we find the first great modernization of the floras of the world due to the seemingly sudden evolution of the main types of angiosperms. These upper Cretaceous floras are well represented in the coastal plain from Marthas Vineyard to Texas. They extended northward to Greenland and southward to Argentina in South America, and are found to indicate very different physical conditions from those which prevail at the present time. I do not intend, however, to dwell upon the Upper Cretaceous floras in this connection but pass to a consideration of the succeeding Eocene stage of plant evolution. In this as in subsequent times the chief emphasis will be laid upon that section known as the embayment or old Mississippi Gulf, although where the record is more complete in other parts of the coastal plain I will not hesitate to use it.

Basal Eocene.

The Eocene as defined by Lyell was marked by the dawn of the recent species of marine mollusca. It is equally well marked by the sudden expansion and evolution of modern types of mammals and plants after a long antecedent Cretaceous development. The floras become thoroughly modernized as compared with those which preceded them, although they are still very different in their general facies and distribution from those of the present.

In the earliest stage of the Eocene known as the Midway, the relations of sea and land in the Gulf area differed in only minor particulars from that of the late Cretaceous. The waters of the Missis-

sippi Gulf were, however, deeper. This factor combined with a much less influx of fresh water from the tributary streams, due in some measure to the low relief of the land, enabled marine faunas to reach well toward the head of the gulf. These faunas indicate subtropical bottom temperatures northward as far as Paducah, Ky. The known floras are very scanty and unsatisfactory and in the present state of our knowledge do not merit an extended discussion.

Lower Eocene.

The Midway Eocene was succeeded by a long interval during which a great thickness of deposits was laid down which are collectively known as the Wilcox Group. The character of these sediments and their faunas show that the gulf was somewhat restricted and much shallower than in the preceding stage, with true marine conditions prevalent only in its lower portion. The shores were low and relatively flat. They were flanked by current- or wave-built bars and separated from the mainland by shallow inlets or lagoons. The lower courses of the streams were transformed into shallow estuaries or broad swamps through which the smaller streams meandered. The accompanying sketch map (Fig. 1) shows the relation of land to water at this time. The shore line along which the strand flora migrated is approximately indicated, and some of the localities where fossil plants have been discovered in the littoral deposits of this age are indicated by stars, while the general movement of the warm ocean currents is indicated by arrows. A magnificent flora is preserved at a large number of localities in the clay lenses which were formed in these estuaries and marginal lagoons. This flora shows a mingling of tropical and subtropical types as far northward as where the Ohio River now flows into the Mississippi. It is of unparalleled richness and preservation and will bear a more extended analysis.

Among the ferns it contains representatives of the genera *Acrostichum, Pteris* and *Lygodium,* none of which appear to be common. Both feather and fan palms are not uncommon. Conifers are represented by a single occurrence of a species of *Arthrotaxis*—a genus which in the living flora is confined to the coastal swamps of Tas-

mania but which is widespread in European Eocene floras. A large variety of dicotyledonous forms are preserved, representatives of about two hundred different species of which about one third have thus far been satisfactorily identified. These include seven or eight species of leguminous shrubs and trees represented by pods as well as leaflets—evidently strand plants, as are numerous modern species

FIG. 1. Sketch map showing the approximate relation of land to water in the Lower Eocene. Stars indicate fossil plant localities, diagonal lining indicates submerged areas.

of *Acacia, Cæsalpinia* and *Dalbergia.* Evergreen lauraceous forms are also abundant, the genera *Cinnamomum, Laurus, Malapoenna, Persea, Oreodaphne* (*Ocotea*), etc., being represented by several species. Figs are abundant and of several species, embracing both

the pinnately veined and the palmately veined types. There are three or four species of *Sapindus*—another strand type of the modern equatorial and subequatorial zones. Other members of the strand flora include representatives of the genera *Conocarpus, Guetteria, Mimusops, Persoonia, Terminalia,* etc. Leaves of several species of live oaks (*Quercus*) are abundant. The collections also include fruits of the families Anacardiaceæ and Umbelliferæ, and of the genus *Aristolochia.* Curious elements common to Europe are several species of *Banksia,* an antipodean genus in the existing flora. There is a fine species of *Cercis,* a very common *Euonymus* and at least two species of *Engelhardtia* based upon the characteristic fruits as well as leaves. The latter genus has a single existing species in Central America and several in Asia, where they range from India to the East Indies. It is common in the European Tertiary, but has not previously been known with certainty from North America. An interesting member of this flora is a large digitate species of *Oreopanax,* a modern tropical type, abundant in Central America.

The flora as a whole contains no strictly temperate elements, although many of the genera contain modern forms which range for more or less considerable distances in the temperate zone. Such a flora could scarcely flourish under existing conditions north of latitude 29°. In its general facies it is subtropical and a number of the forms indicate a high percentage of humidity, and well distributed and abundant seasonal rains, although this latter feature tends to be obscured by the large number of the inhabitants of the sandy shores which are preserved while the inland and river bank dwellers are less fully represented. A majority of the elements in this Wilcox flora could be duplicated today on the Florida Keys and the southern peninsular mainland of Florida.

Additional members of this flora not enumerated in the preceding paragraphs include representatives of the genera *Apocynophyllum, Calamopsis, Ceanothus, Celastrus, Celtis, Cordia, Diospyros, Dryophyllum, Magnolia, Malpighiastrum, Nerium, Rhamnus, Rhus, Sabal, Sapotacites,* etc., nearly all of which are new to science.

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Middle Eocene.

Middle Eocene floras are less abundant than those of the Lower Eocene since this period is marked by a considerable subsidence and deeper waters in the Mississippi Gulf, which, however, eventually

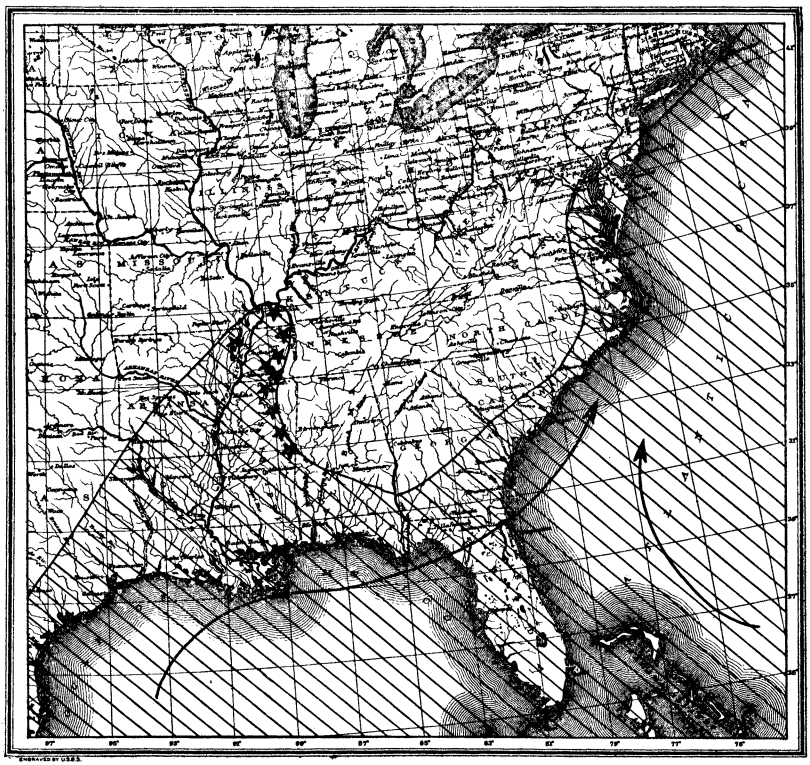

Fig. 2. Sketch map showing the approximate relation of land to water in the Middle Eocene. Stars indicate fossil plant localities, diagonal lining indicates submerged areas.

became shallower again and duplicated in a measure the Lower Eocene conditions.

At a number of localities in Georgia and at two or three in northern Mississippi and in Arkansas representatives of the Middle Eocene flora have been collected. In Georgia where the plants are associated with shallow water and estuarine invertebrates I found

the remains of a typical mangrove flora associated with types which today characterize the tropical and subtropical beach jungle. This flora includes an *Acrostichum* closely allied to the modern *Acrostichum aureum* Linné which is such an abundant fern in the mangrove and nipa tidal swamps. Other genera represented by fossil forms are *Conocarpus, Dodonæa, Ficus, Malapœnna, Pisonia, Momisia, Rhizophora, Sapindus, Terminalia,* and palms of the genus *Thrinax.* Botanists familiar with the flora of the torrid zone will recognize at once that this is a typical strand flora of the tropics which might almost have been taken bodily from Schimper's classic Indomalayan Strand Flora, or which can be seen today along the Florida Keys and in the West Indies.

The plants of this age from Mississippi and Arkansas do not indicate such a well marked ecological group nor quite such high temperatures as those from Georgia, nevertheless they also are largely subtropical coastal types and embrace species of *Sabal, Rhamnus, Panax, Ficus, Dryandroides, Persea, Sapindus,* etc. One of the most interesting forms abundantly represented in northeastern Arkansas is a citraceous form with alate petioles which I have named *Citrophyllum.* Additional genera which are present are *Nectandra* and the coniferous genus *Arthrotaxis.*

In Fig. 2 is shown the approximate position of the shore line along which the mangrove and the tropical beach flora migrated northward in the path of northerly flowing tropical ocean currents.

Upper Eocene.

No upper Eocene floras are known from the coastal plain but it is believed that future discovery will reveal their presence when the area where they are likely to occur shall have been examined in detail.

Lower Oligocene.

The Lower Oligocene has yielded no plants except petrified fragments of the wood of palms and dicotyledons. The sediments are more or less impure marine limestones, and if marginal deposits with plants were laid down they were subsequently destroyed by erosion, or have not yet been discovered.

Extensive marine faunas indicate even more torrid conditions than in the preceding epoch, uniformly distributed over this whole area.

Middle Oligocene.

The Middle Oligocene deposits are those of shallow tropical waters with a bottom temperature of at least 39° C. (70° F.), marine toward the east with true reef corals in Georgia, but becoming brackish or fresh toward the west, by reason of their shallowness and the increased volume of fresh water from the Oligocene Mississippi and Tennessee rivers and other streams. The flora is scanty but includes tropical swamp types, the fern genus *Acrostichum* being the most abundant form collected.

The accompanying sketch map (Fig. 3) shows in a generalized way the relation of land and water in the Middle and Upper Oligocene. It is to be noted that the great Mississippi Gulf had been reduced to a very wide and shallow reentrant.

Upper Oligocene.

Toward the close of the Oligocene a widespread emergence of the land was inaugurated accompanied by a slight lowering of temperatures. The floras are not abundant but are represented in western Florida and central Mississippi. They contain very abundant remains of several species of *Sabal*-like palms; the large leaves of a species of *Artocarpus* or breadfruit; leaves of figs; of the *Cinnamomum* or camphor tree; representatives of the genera *Acacia, Bumelia, Diospyros, Pisonia, Gyminda, Gleditsia, Nectandra, Sapotacites, Rhamnus, Ulmus,* etc.—the latter being the only genus which is a strictly temperate type in the modern flora, although most of the genera enumerated have representatives in the warmer parts of the temperate zone at the present time.

Miocene.

A long interval followed the close of the Oligocene, during which the coast line of southeastern North America was considerably seaward from its present position, in consequence of which deposits

FIG. 3. Sketch map showing the relation of land to water in the Middle and Upper Oligocene. Stars indicate fossil plant localities, diagonal lining indicates submerged areas.

of this age are unknown. This interval comprises the first half of the Miocene age and when renewed submergence furnishes us with a record we find very different conditions from those previously enumerated. Either because of the diversion of the gulf stream to the eastward due to the emergence of peninsular Florida or as a result of changes in depth off the Hatteras anticline, a cool inshore current seems to have swept southward along the coast and through the Suwannee Strait across northern peninsular Florida, carrying with it a northern marine fauna which replaced the tropical fauna that had previously occupied this region.

The fossil plants of this age are unfortunately rare and are as yet unknown south of the Maryland-Virginia area. The accompanying sketch map (Fig. 4) shows in a generalized way the upper Miocene conditions after the resubmergence of the area, the maximum emergence during the lower Miocene being unknown. The

FIG. 4. Sketch map showing the approximate relation of land to water in the Upper Miocene. Stars indicate fossil plant localities, diagonal lining indicates submerged areas.

land masses southeast of the mainland are to be noted as well as the supposed directions of the ocean currents.

The known fossil plants from the Atlantic coast Miocene, exclusive of diatoms, include the following species from the Maryland area near Washington described by Hollick:[2]

[2] Hollick, Md. Geol. Surv., Miocene, 1904, pp. 483–486, tf. a–b.

Quercus Lehmanni Holl.
Ulmus basicordata Holl.
Cæsalpinia ovalifolia Holl.
Rhus Milleri Holl.
Pieris scrobiculata Holl.
Phyllites sp., Holl.

In addition to the above the following have been described from the same horizon at Richmond, Va., by Berry:[3]

Salvinia formosa Heer?
Taxodium distichum miocenum Heer.
Salix Raeana Heer.
Carpinus grandis Unger.
Quercus calvertonensis Berry.
Rhus Milleri Holl.
Planera Ungeri Ettings.
Ficus richmondensis Berry.
Platanus aceroides Goeppert.
Podogonium? virginianum Berry.
Dalbergia calvertonensis Berry.
Celastrus Bruckmanni Al. Br.
Nyssa gracilis Berry.
Fraxinus richmondensis Berry.

These plants indicate that the coast was low, which explains the absence of any but the finest terrigenous materials in the shallow water deposits which constitute the Calvert formation. The flora from Virginia indicates the presence of extensive cypress swamps, the latter type of plant being the most abundant fossil collected and the other plants identified being for the most part similar in their physiological demands upon their environment. The flora from Maryland is the natural counterpart of that from Virginia in containing several typical elements of just the sort of a plant association found on sands (inner beaches and more or less stationary dunes) along the present coasts in the temperate zone.

Regarding age the plants are clearly Middle Miocene according to European standards. They indicate less conclusively the climatic

[3] Berry, *Journ. Geol.*, Vol. 17, 1909, pp. 19–30, tf. 1–11.

conditions which prevailed along the Miocene coast in this latitude. There is considerable evidence of a scant rainfall, that is to say of less than 30 inches annually but this may well have been merely a coastal condition. Indirectly the lack of land derived sediments in the deposits points to the conclusion that relatively dry conditions extended over wider areas. The mean annual temperature is difficult to determine. Several of the closely allied modern plants such as the existing bald cypress do not extend north of Maryland in the existing flora, while *Ficus* does not fruit north of Virginia, which also marks the northern limit of *Planera*. However, the Miocene forms enumerated are all different specifically from the existing members of their respective genera and the conclusion is reached that the Calvert flora would grow under the climatic conditions prevailing at the present time between Sandy Hook, N. J., and Cape Henry, Va., and that the mean annual temperature which they indicate is between 50° and 55° F.

Pliocene.

Pliocene floras have been unknown from North America until last year when deposits of this age with abundant fossil plants were discovered in southern Alabama. The most remarkable form in this flora is the fruit of *Trapa*, the water nut, which Raimann in Engler and Prantl segregates from the family Onagraceæ to form the family Hydrocaryaceæ. In the existing flora this genus has only three species of southern Europe and southeastern Asia but it is well known in the older Tertiary of North America and Europe and in the later fossil floras of Europe. Another interesting species in this Alabama Pliocene flora is a species of *Glyptostrobus*, a coniferous genus allied to our bald cypress which is now confined to eastern Asia, but which appears to have been cosmopolitan in Tertiary times. Other elements of this flora are abundant live-oaks (*Quercus*); several species of elm (*Ulmus*); abundant twigs, seeds and cone scales of a species of cypress which is very close to the existing bald cypress (*Taxodium*). Additional elements are species of *Nyssa, Hicoria, Planera, Betula, Dioscorea, Prunus, Pinus*, etc. This flora is quite modern in its facies and is a mixture of swamp

types and those of live-oak barrens. Among existing localities which I have visited which impress me as duplicating the climatic and other physical conditions indicated by this late Pliocene flora are the estuaries along the gulf coast of Alabama and western Florida, among which Apalachicola, Mobile, Perdido and Pensacola bays are the larger. The Santa Rosa peninsula which separates the latter from the Gulf of Mexico supports a flora that is very similar to this Pliocene flora and one or two of the species represented in both are closely allied and may even be identical.

Pleistocene.

Pleistocene plants are also common throughout most of the coastal plain and when they shall have been thoroughly studied they will yield a large body of exact facts which will throw much light upon the immediate ancestry and migrations of our existing flora. Already more than one hundred species have been recorded, most of which are still existing and these indicate a very different geographical distribution from that of the present coastal plain flora.

Conclusion.

I have only had time in the foregoing remarks for a very fragmentary and incomplete sketch of the present study which has really only just commenced. With the complete exploration of the area and the additional collections which it is hoped to make it is believed that the combined results of the speakers studies of the fossil floras and those of his associates on the fossil faunas and the areal geology will furnish a basis for reconstructing the physical, faunal and floral history of the southern states, during the several millions of years from the Cretaceous to the present, which will constitute a lasting contribution to the history of the earth.